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54 Autonomous modular energy supply system for separate networks

57 The object of the invention is to design an autonomous modular wind/photovoltaic battery/diesel system in which the synchronous machine, which had been necessary in the past for network control, is replaced and a system is developed with which active and reactive power compensation with voltage injection on the direct current side can occur. In addition, system modularity and efficiency are to be attained by using tested components that are available on the market.
This object is attained in that, instead of a network-controlled reversible converter for active power compensation and a synchronous machine phase shifter for reactive power compensation, an uninterruptible power supply (UPS) is used at the input of an attached emergency power-generating set. Such uninterruptible power supplies are known in and of themselves and are today used e.g. for supplying power to computer systems. In this case they are to be employed in a modified form for separate network energy supply.

[column 1]

Description

The invention relates to a method for autonomous modular energy supply with photovoltaic and wind energy feed for supplying consumers with electrical energy from a separate network.

In recent years it has become increasingly common to obtain electrical energy from the sun and wind, particularly in remote areas. Due to rising energy prices, using wind energy in particular has become more economical.

Given this background, autonomous energy supply systems have been developed with hybrid technology, making it possible to turn the diesel engine off when there are sufficient quantities of sun and wind energy available. Using the existing energy storage unit makes it possible to minimize diesel engine running times and the number of its starts. The use of a battery storage unit that is supplied by a power converter and that works in parallel makes it possible to supply energy to the separate network from the battery during periods of weak winds and thus to be able to provide a certain active power compensation to compensate fluctuations in load. Such a system with a synchronous machine as a rotating phase shifter has been developed in recent years; today it is successfully employed e.g. on the Irish island of Cape Clear (see G. Cramer, R. Grebe (SMA Regelsysteme GmbH), Wind/Diesel/Battery System on Cape Clear, Ireland, Status Report for the Year 1990 on Research Plan O3E-8536-B, Federal Minister of Research and Technology).

One disadvantage of this system is caused by the fact that for network control, i.e., for voltage stability and reactive power compensation, at least one synchronous machine must run continuously in the phase shifter mode. Its nominal power is matched to that of the network and because of this is responsible for significant no-load losses, noises, and maintenance expenses, which can be reduced substantially by employing a self-commutated converter with modern power semiconductors; see e.g. Ch. Duca, F. Feilcke, Efficiency-Optimized UPS System, etz. Volume 111 (1990), notebook 20, pp. 1048 – 1057. Efficiency and voltage/frequency stability of the entire system can be improved using efficiency enhancements and by increasing the control dynamics.

Recently modern wind converters with power converter feed and that have a 5 – 20% higher energy yield have also come onto the market. However, these cannot be connected to the present wind/photovoltaic battery/diesel system with nothing further because they cause severe reactive power fluctuations that cannot be adequately dynamically compensated because of the low control dynamics.

The object of the invention is to design an autonomous modular wind/photovoltaic battery/diesel system in which the synchronous machine, which had been necessary in the past for network control, is replaced and a system is developed with which active and reactive power compensation with voltage injection on the direct current side can occur. In addition, system modularity and efficiency are to be attained by using tested components that are available on the market.

[column 2]

This object is attained in accordance with the characterizing features of claim 1; advantageous embodiments can be found in the subordinate claims.

Instead of a network-controlled reversible converter for active power compensation, i.e., for charging and discharging a battery, and a synchronous machine phase shifter for reactive power compensation, an uninterruptible power supply (UPS) is used at the input of an attached emergency power-generating set. Such uninterruptible power supplies are known in and of themselves and are today used e.g. for specifically supplying power to computer systems. In this case they are to be employed in a modified form for separate network energy supply.

The invention is explained in greater detail in the following using exemplary embodiments. Fig. 1 illustrates the structural principles of such a system. Fig. 2 is an exemplary embodiment for one autonomous energy supply.

Fig. 1 illustrates a separate network 1 that in terms of a system is fed via a distribution transformer 3d by a self-commutated converter 3c from a battery 3b. The battery 3b itself, in addition to charging by the self-commutated inverter 3c during energy recovery, when there is sufficient energy feed through the photovoltaic system 4 or through the wind converter 5, can also be supplied with electrical energy via an emergency power-generating set 3f, 3g, whereby a controlled rectifier 3a acts as battery charging device. The task of the self-commutated converter 3c is to keep the network voltage of the separate network 1 largely constant despite a fluctuating energy supply (wind) and changing loads 6. A filter system 2 compensates the current harmonics in the network that are caused by the network-controlled power converters 4a, 5a. The filter system 2 also provides fundamental reactive power compensation to the extent that foreseeable static portions are involved. The dynamic portions that are causally related to voltage fluctuations are given off (capacitive) or received (inductive) by the self-commutated converter 3c.

As electrochemical storage unit, the battery 3b is designed such that the difference between energy supply and demand can be covered (so-called efficiency compensation). In this manner the diesel set 3f, 3g becomes the emergency power-generating set, which only operates when the minimum charge condition of the battery drops below a certain level. This has a number of advantages. For one thing, the operation of the diesel motor is reduced to approx. 0 – 30% of the total operating time of the system, which means substantial fuel savings. For another thing, at times of low energy supply, the emergency power-generating set can be employed for simultaneously charging the battery and supplying the consumers by closing the transition device 3e. The diesel set is thus predominantly operated under a full load, which leads to further fuel savings, because full load operations generally have better efficiency than operating in the partial load range.

There are currently two different types of wind converters. There are partially wind-controlled systems with variable speed and converter power control 5a. In these systems, the rotation of the rotor 5d or that of the synchronous machine 5b, which is coupled thereto via a gear unit 5c,

[column 3]

is matched to the wind speed. This increases the energy yield. In wind converter systems with semi-fixed rotation, there is no electronic power control. Instead of the synchronous machine 5b, an asynchronous machine 5e is used that itself adjusts its slip corresponding to the wind supply. In both system types, the reactive power required for operation is provided by the UPS system. and the filter 2. This also applies for the reactive power that the network-controlled power converter of the photovoltaic system and the consumers receive.

Energy management of the system is performed by the system management device 7, which comprises a conventional automation system with appropriate software.

Fig. 2 illustrates an exemplary embodiment for autonomous energy supply, as planned for a Greek island with approx. 300 MWh/a energy consumption. The three-phase 400 V separate network with 50 Hz network frequency is fed with two UPS systems 3, 3' that can each be supplied with 60 kVA by an emergency power-generating set 3gf, 3'gf. An additional 40 kVA-module 3 covers overloads during periods of low sun and wind supply. This is then switched by means of the thyristor transition device 3h to the network 1, whereby it automatically synchronizes to the network voltage that is delivered by the two self-commutated inverters 3e, 3e' of the UPS system.

The installed power of this energy supply system is determined by the maximum removable consumer power 6, 6', which here is divided into two groups with different supply priorities.

At an assumed consumer power of e.g. 150 kW or 200 kVA, the type powers of both UPS systems are 100 kVA each. They thus cover the reactive power of the two wind converter systems 5, 5' with 80 kW_p (100 kVA) and that of the photovoltaic system 4 with 25 kW_p (40 kVA). The required reactive power of the solar and wind generators that work in parallel via connected network-controlled power converters is therefore at a mean assumed power factor of $\cos\varphi = 0.8$ $Q\ \Sigma = (2 \times 60 + 24)$ kVAr approx. 150 kVA4.

50 kVAr are left over as control reserve for the UPS system for voltage stabilization. The consumer reactive power in the amount of 120 kVAr (ind.) is covered by the filter 2. It also compensates the harmonic oscillations from the converter currents.

In normal operations, the active power of the consumers in the amount of 150 kW is covered by the wind converters 5, 5' and the solar generator 4, whereby the active power fluctuations of the UPS system are equalized. The batteries are dimensioned such that the difference between the supplied and demanded instantaneous power can be covered without the emergency power-generating sets 3gf, 3'gf having to be turned on. Thus it is possible to feed the consumers from the regenerative sources.

It is not until the batteries are discharged and the demanded power has not decreased that all of the emergency power-generating sets are started. The difference from the demanded consumer power and the nominal power of the emergency power-generating sets contributes to charging the batteries.

[column 4]

If the supply of solar and wind energy decreases even further, the consumers with lower priority 6' are turned off until all of the batteries are recharged.

In the case of a very extended network, for voltage stabilization a UPS system without emergency power-generating set 7 can be installed at the end of a stub line for equalizing the active and reactive current pulsation. In this manner the flickering, caused by switching in the network and voltage drops on the line, can be avoided with devices of the same technology or the short-circuit power at these locations can be increased to the desired value.

If one or two of the self-commutated converters 3c, 3'c of the UPS system fail, the associated power switch 3l is closed and all three emergency power-generating sets are started. The system is designed such that in this case network control is assumed by the synchronous machines and the system can operate at the nominal load even when there is a malfunction. The consumer power does not have to be lowered by turning off the consumer group with lower priority 6' until additional units fail. At this point naturally fuel consumption, waste gasses, and the noise from of the emergency power-generating set are disadvantageous.

Patent claims

1. Method for autonomous modular energy supply with photovoltaic and wind energy feed for supplying consumers with electrical energy from a separate network, characterized in that for network control with uninterruptible power supply (UPS) an arrangement 3 comprising a network-controlled power converter (3a), a battery (3b), a self-commutated converter (3c), a transformer (3d), a filter circuit (2), and an emergency power-generating set (3f, 3g) with transition device (3e) is used in which [arrangement] during normal operation said emergency power-generating unit (3f, 3g) is turned off, and photovoltaic and wind converter systems (4, 5) supply said consumers (6) and charge said battery (3b) via said self-commutated inverter (3c), and in that only when there is not adequate feed from the regenerative energy sources, sun and wind, the energy deficit is covered in the reverse direction initially from said battery (3b) and, if this is not sufficient for filling the gaps in the energy supply, by means of said emergency power-generating set (3f, 3g).
2. Method in accordance with claim 1, characterized in that when said emergency power-generating set (3f, 3g) is turned on for charging said battery (3b), said transition device (3e) is turned on by said system control (7) for electrically connecting said emergency power-generating set (3f, 3g) to the separate network (1) and the electrical energy generated by said set is used for charging said battery (3b) and for supplying said consumers (6).
3. Method in accordance with claim 1 or 2, characterized in that for increasing availability when said self-commutated converter (3c) fails, said emergency power-generating set (3f, 3g) is started, said transition device (3e) is closed and said consumers (6) and the network control

[column 5]

are taken over by said synchronous machine (3g) of said emergency power-generating unit.

4. Method in accordance with any of the preceding claims, characterized in that in the case of redundant emergency power-generating sets and UPS systems, one UPS system is coupled to each emergency power-generating set and these are operated in a synchronized manner for increasing the power in the network.
5. Method in accordance with any of the preceding claims, characterized in that for reactive reactive power compensation and harmonic current compensation in spurs of said separate network a filter system (2) or a UPS system without connected emergency power-generating set (3f, 3g) and network-controlled power converter (3a) is provided, whereby the UPS system can also be used for active current compensation in addition to reactive current compensation when the battery is designed appropriately (3b).
6. Method in accordance with any of the preceding claims, characterized in that for long-term energy storage a pumped-storage unit with hydro-electric generators is provided.
7. Method in accordance with any of the preceding claims, characterized in that for reversible long-term energy storage in the direct current intermediate circuit of the UPS system, parallel with or instead of the battery (3b), a fuel cell with electrolyzer unit or a reversible fuel cell with hydrogen as secondary carrier is used.

2 page(s) of drawings

[In drawings, Betriebsführung = system management]

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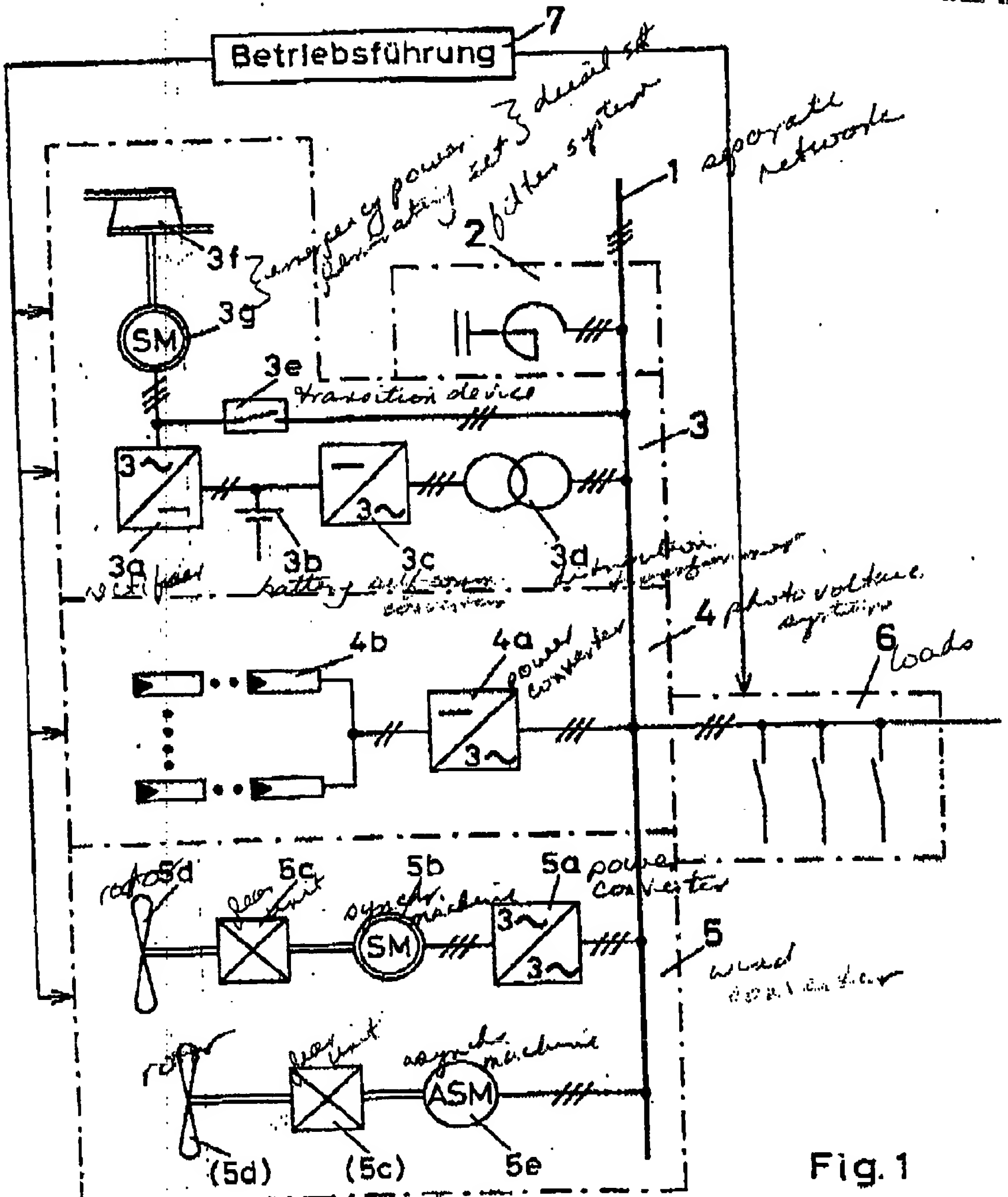

Fig. 1

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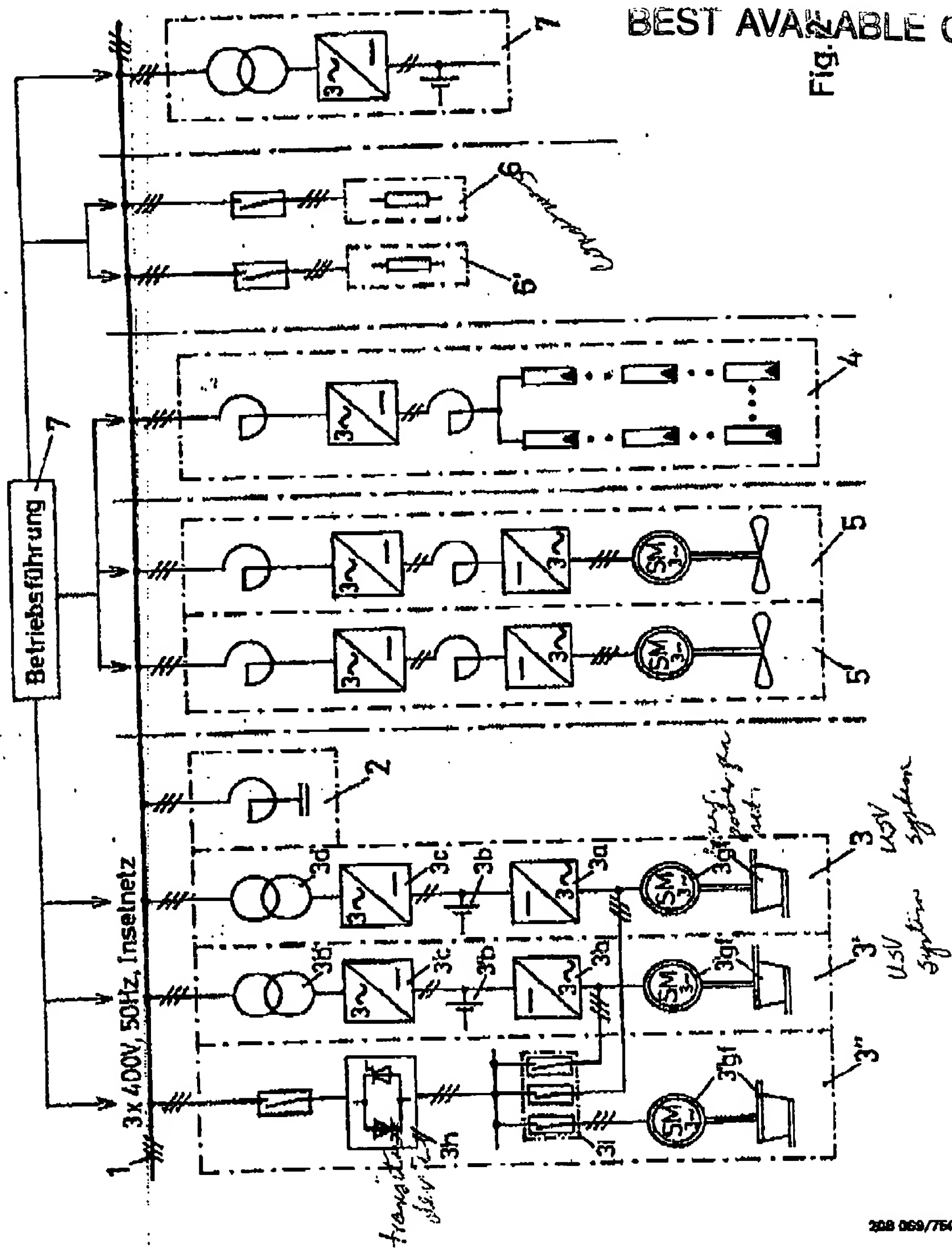

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